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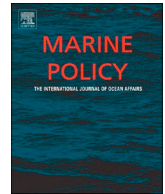
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Invasive lionfish in the Mediterranean: Low public awareness yet high stakeholder concerns

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ABSTRACT

A lionfish invasion in the Western Atlantic has been one of the most ecologically harmful fish invasions to date. Experience there has shown that its management is most effective when the public and stakeholders are involved. The lionfish (*Pterois miles*) has recently invaded the Mediterranean, spreading at an alarming rate. To understand lionfish knowledge and perceptions, questionnaire surveys were conducted with a representative cross section of the adult general public (via telephone) and stakeholders (via organised meetings) in Cyprus. Results from 300 public surveys revealed limited awareness about the lionfish but strong support for its local management. Men and older respondents showed stronger support compared to women and younger respondents, respectively. Results from 108 stakeholder revealed high level of awareness and almost unanimous support for management measures. The majority had not experienced any effects from the recent lionfish invasion, but some reported negative impacts such as limited access to dive sites, ecosystem damage and fishing gear destruction. Few stakeholders perceived benefits of this invasive species, e.g. to dive tourism or as a food source. Almost all stakeholders expressed a willingness to get involved in lionfish management, but only around half would consider personal consumption, or sports incentives as good incentives for their participation. Encouragement from scientists through co-ordination, training and support was suggested as an essential part of effective management strategy. The results of this study can inform an efficient adaptive management process across the Mediterranean region and assist future engagement of citizen scientists in lionfish control and mitigation.

1. Introduction

Marine invasive species are adding to cumulative pressures such as overfishing and climate change which in combination are causing rapid changes in coastal marine ecosystems worldwide [1]. Due to the inherent connectivity of marine systems, invasive species are spreading unchecked and causing widespread environmental change, disrupting ecological functions and in some cases causing fisheries collapses [2,3]. A lionfish (*Pterois miles*/*Pterois volitans* complex) invasion in the Western Atlantic has been characterised as the most ecologically harmful marine fish invasion to date, responsible for significant impacts on the biodiversity and ecological functions of the region [4].

The impacts of the lionfish in the Western Atlantic are associated to habitat modification [5,6] and declines in the local biodiversity. With high predation rates, lionfish reduces the abundance and recruitment of

native biota [7–11] and outcompetes native predators [12,13]. While socio-economic impacts have yet to be fully evaluated, the lionfish complex has still the potential to reduce the native fish recruitment success by a significant amount (up to 95%, on experimental sites) [14] and further lower fisheries yields on economically important fish [15]. The biological traits of lionfish, such as early maturity, high growth rates, generalist diet, high reproductive rates, generalist habitat use, long-range larval dispersal, and effective physical and behavioural defences (i.e. venomous spines which are posed in case of a perceived threat, and resistance to ectoparasites) favour its invasive character and successful spread across regions (Fig. 1) [16].

Evidence from throughout the eastern Mediterranean shows that a lionfish (*Pterois miles*) invasion is now underway [17,18]. Following an unsuccessful invasion in 1991 (Golani & Sonin, 1992), the lionfish were recorded again in 2012 off Lebanon, and numbers have quickly

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Fig. 1. Illustration of a lionfish from the Mediterranean. The lionfish is posing its venomous spines after perceived threat.

proliferated and spread, reaching the central Mediterranean Sea in just three years and becoming increasingly abundant along the entire eastern basin [19]. Genetic work revealed that the first lionfish individuals were most likely introduced in the Mediterranean via the Suez Canal [20,21]. Cyprus sentinel location near the Suez Canal was the first Mediterranean country where lionfish were initially reported to be established, forming pairs along the eastern side of the island [18,22].

Complete removal of lionfish is currently unrealistic and efforts are shifting towards understanding and control. Its control however, poses a number of challenges, which can include a lack of on site management resources, divergent stakeholder views about the value of invasive species and opposition to removal techniques [23]. Experience of trying to manage a lionfish outbreak in the Western Atlantic has shown that it is necessary to build a socioeconomic understanding of effective management strategies through a programme of research and management [24].

The EC Directive 2003/35/EC established a framework for public consultation in environment-related decisions, its objectives are to improve public participation and involve them in drawing up plans and programmes related to sustainable use of the environment. Moreover, the European Regulation 1143/2014 on invasive species highlights the importance of public participation in bringing about effective and timely action to tackle invasive species. Engagement of the public and stakeholders is seen as essential in tackling lionfish invasion in the Western Atlantic; either through the development of a commercial lionfish market or through the participation of citizen-scientists in monitoring and removing lionfish, particularly in areas where commercial fishing is either not permitted or impractical [23,25]. Therefore, understanding the perceptions and behaviour of the public and stakeholders is critical towards effective lionfish management.

In this study, a telephone survey was used to census a representative

cross section of adults in Cyprus while a series of marine stakeholder meetings was held throughout the country to identify baseline understanding and awareness of the public and stakeholders in relation to lionfish. The questionnaires were designed to record the current interactions of people with lionfish and identify any possible impacts they may have. We also sought suggestions from the public and stakeholders on how to respond to the spread of lionfish in the Mediterranean. Here we report on the results of these surveys and discuss the findings in a wider management framework for lionfish.

2. Methods

2.1. Survey

Questionnaires combined qualitative and quantitative questions designed to assess general public and marine stakeholder knowledge and perceptions of lionfish. Questions to the public fell into three broad topics; those to marine stakeholders fell into seven topics (Table 1). The full set of questions used is presented in the Supplementary material. Members of the general public were contacted using a telephone survey of 300 permanent Cypriot citizens between 20 October to 6 November 2017. Stratified random sampling was used to obtain responses from a representative spread of citizens aged between 18 and 76 years old living in urban, semi-urban and rural regions of Cyprus. Marine stakeholders were defined as members of the public who make use of the marine environment as a resource (e.g. anglers and divers) as well as people involved in the decision-making such as the Governmental Authorities and Non-Governmental Organisations. Marine stakeholders were interviewed during meetings carried out across different districts of Cyprus; namely Limassol, Paphos, Nicosia, Larnaca, and Famagusta (i.e. Protaras), between 7/11/2017 and 23/11/2017.

2.2. Data sorting and statistical analysis

Once data collection was completed, all data were pooled. Values from dichotomous (Yes/No) and scale questions (ranking order of preference: 0–10) were entered directly, and key points from open-ended questions were detailed in the same spreadsheet.

Initially, the statistical analysis focused on the differences between the public and the stakeholders for the questions related to perceptions on lionfish and future strategies; which have been asked to both groups. The dichotomous questions were analysed using a Pearson's chi squared test with Yate's continuity correction to test for equal proportions for each scoring category. For scale questions, comparisons between public and stakeholders were focused on two approaches. Firstly, the two groups were tested for differences on their overall scoring tendency based on the ordinal scores using a Mann-Whitney *U* test. Secondly, the ranking order of preference in each question was binned into 3 nominal agreement categories including disagree (ordinal numbers: 0–4), neutral (ordinal number: 5) and agree (ordinal numbers: 6–10) and tested for equal proportions for each of those groups using a Pearson's chi

Table 1

Broad topics covered in lionfish questionnaires to the public and to the marine stakeholders.

Public telephone surveys (n = 300)	Marine stakeholder meetings (n = 108)
Perceptions on lionfish and its potential to cause damages to the environment, economy and human health	Perceptions on lionfish and its potential to cause damages to the environment, economy and human health
Perceptions on future strategies	Perceptions on future strategies
Socio-demographics	Abundance of lionfish
	Effects of lionfish
	Management of lionfish
	Socio-demographics

squared test or Fisher's test, when sample size in one or more cells was below 5. Potential “I don't know” responses were analysed separately and statistically tested with a two-proportion's test with Yate's continuity correction.

The public and the stakeholders were then analysed independently to unravel which of the demographics (i.e. gender, age, education and district) might have played an important role in their responses. For dichotomous questions, a Binomial GLM (Bernoulli GLM) was run, and for the Likert scale questions, a motivational score was calculated as the sum of each respondent's scores from all the questions. A multiple linear regression was conducted after the application of a box cox transformation to satisfy the normal distribution and the homoscedasticity of the errors, which were verified via a Shapiro-Wilk test and Breusch-Pagan test, respectively. For demographics that showed to play a significant role in the motivational scores, they were tested independently to observe which of the levels differed, using non-parametric tests: Mann-Whitney *U* test when factor comprised two levels or Kruskal-Wallis followed by a Dunn's test with Bonferroni correction, when factor had more than two levels.

For all the statistical analyses, null responses were excluded, and the level of significance α was adjusted to 0.05. All graphics were generated in R-studio; more specifically dichotomous scale and ordinal scale graphs were produced using ‘Likert’ package [26].

3. Results

3.1. Demographic information

The public respondents reflected the actual population distribution of the Republic of Cyprus. More than half were women (60%) with most of the respondents being residents of Nicosia (40%), followed by Limassol (27%), Larnaca (16%), Paphos (11%) and Famagusta (5%). The public's respondents ranged from 18 to 76 years old, with the majority (61%) being represented by people of 40–64 years old. Most of the public respondents had university or college education (61%).

The majority of the stakeholders were men (79%) of age between 14 and 68 years old. Stakeholders of different education level, age, and districts contributed in the surveys. Most of them, however, were graduates of university or college education (56%), of ages 25–39 (44%) and 40–64 (42%) years old, and mainly residents of the three districts; Limassol (30%), Larnaca (25%), and Famagusta (24%).

3.2. Public vs stakeholders knowledge and perceptions about lionfish

There were significant differences between the public and the stakeholders in the knowledge and perceptions about lionfish; specifically if they heard about lionfish, if they would recognise it in TV or live, and

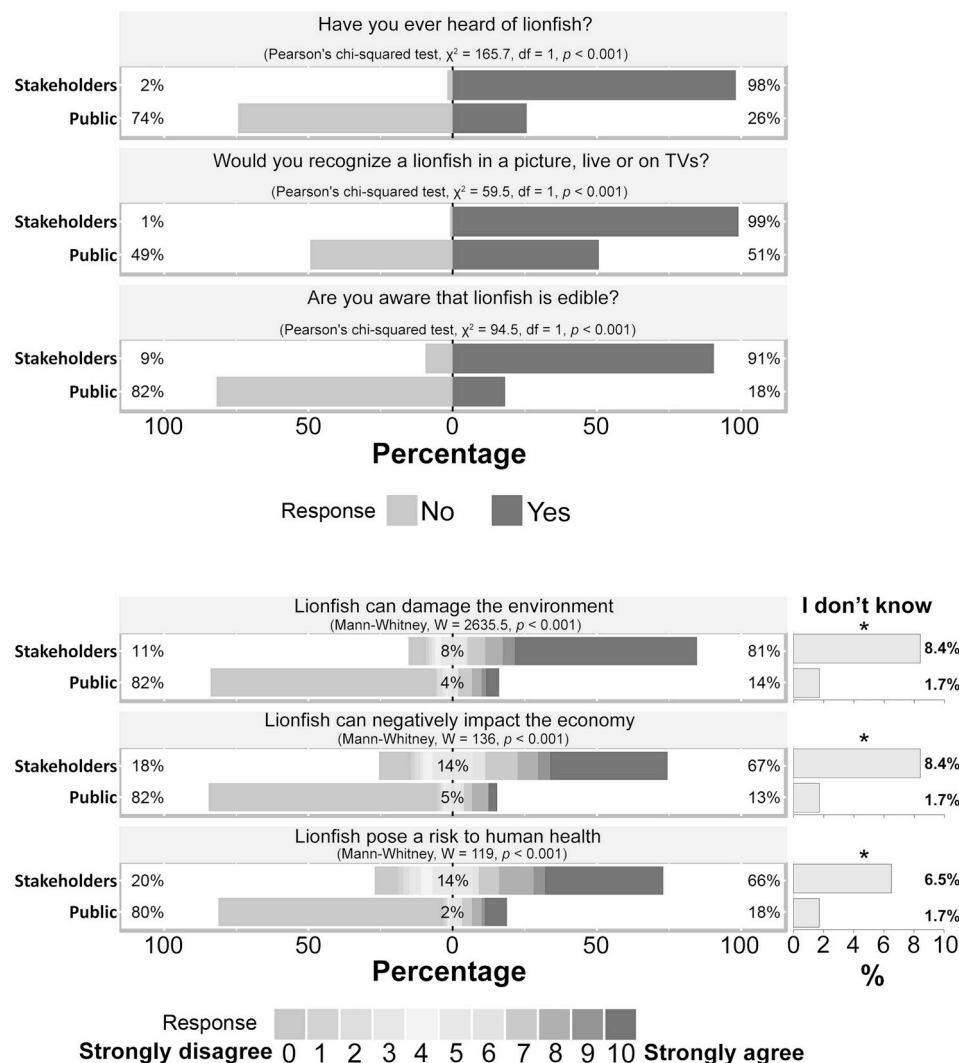


Fig. 2. Stakeholders and public knowledge and perceptions about lionfish. Proportions for ordinal scores were acquired based on their categorisation to disagree (0–4), neutral (5) and agree (6–10). Statistical differences between the public and the stakeholders are presented below each statement. **Note:** Asterisks (*) represent statistically significant difference (2-Proportions test, $p < 0.05$) concerning the “I don't know” responses between public and stakeholders.

if they know that it is edible. Most of the stakeholders had heard about lionfish, could recognise it and knew that it is edible (Fig. 2). The majority of public was unaware of lionfish. From those that were aware about lionfish, half of them would recognise it in a picture, live or on TV and only a small percentage of the respondents were aware that lionfish are edible (Fig. 2).

The opinion of the public and the stakeholders also differed significantly when asked to scale if lionfish can damage the environment, if lionfish can negatively impact the economy and if lionfish pose a risk to human health. Significantly more members of the public did not think that lionfish could damage the environment, negatively impact the economy, or pose a risk to human health (Fig. 2).

3.3. Future strategies

Stakeholders and the public were asked their agreement concerning management strategy measures and options using the scale 0 to 10. The

statements are presented in Fig. 3.

For the first statement the stakeholders appeared to respond similarly with the public, where either showed to disagree/agree or being neutral equally the same (Fisher's exact test, $p > 0.05$) (Fig. 3). In the second and third statement, both the public and the stakeholders responded the same to each of the agreement categories (Fisher's exact test, $p > 0.05$), but their overall degree of scoring varied significantly (Fig. 3). For the fourth statement, the two groups showed the same response tendency overall as well as to each of the agreement categories (Pearson's chi-squared test, $\chi^2 = 0.5$, $df = 2$, $p > 0.05$) (Fig. 3). While the above statements were associated with a strong positive response from both groups to support the project's aims and the requirement of a management strategy (Fig. 3), the following statements rather displayed a striking contrast concerning their perceptions. For instance, when the two groups were asked if they would consume lionfish and if they would buy products made from lionfish, the response tendency between stakeholders and the public differed significantly, where

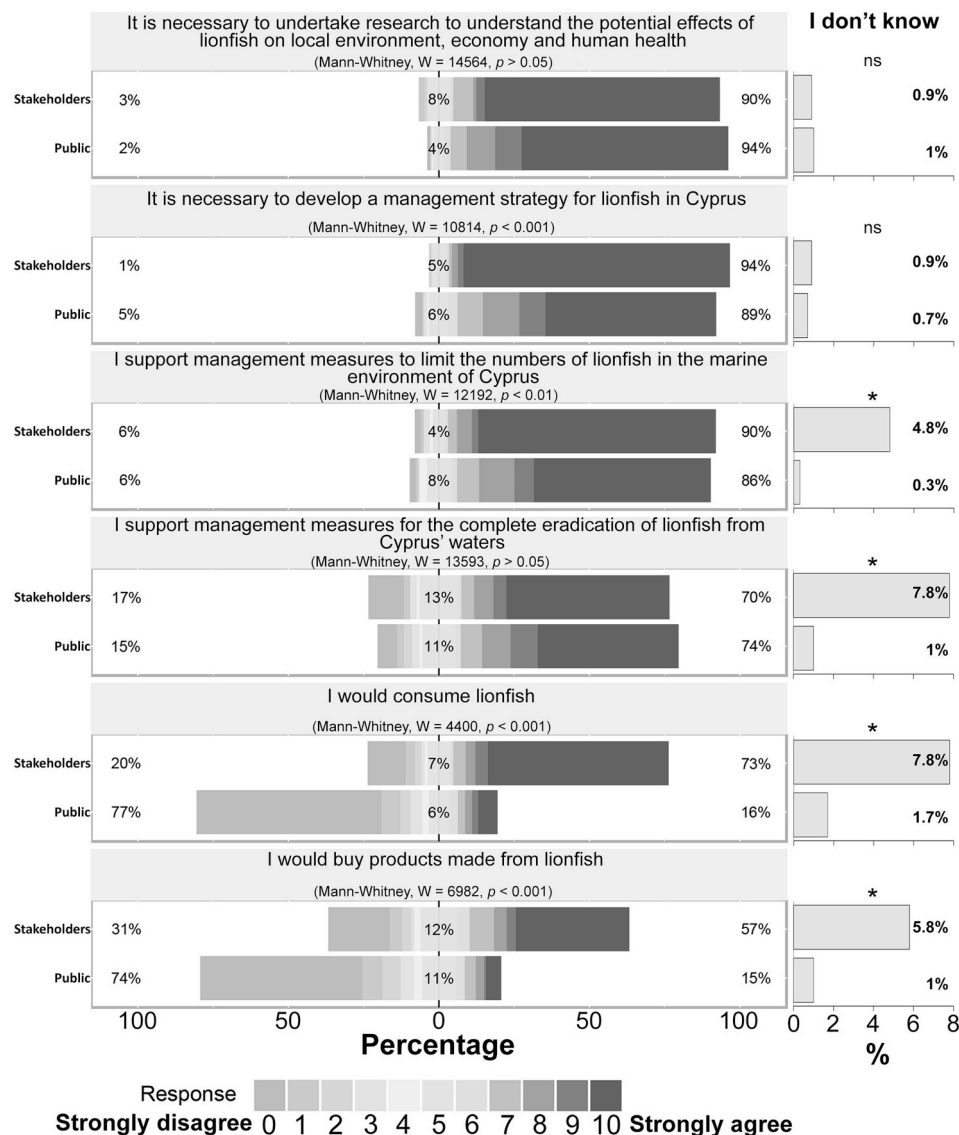


Fig. 3. Agreement of the stakeholders and the public on different management measures and strategies. Proportions were acquired based on the categorisation of the ordinal scores (0–10) to disagree (0–4), neutral (5) and agree (6–10). Statistical differences between the public and the stakeholders are presented below each statement. **Note:** Asterisks (*) represent statistically significant difference (2-Proportions test, $p < 0.05$) and ns designate not significant (2-Proportions test, $p > 0.05$) concerning the “I don't know” responses between public and stakeholders.

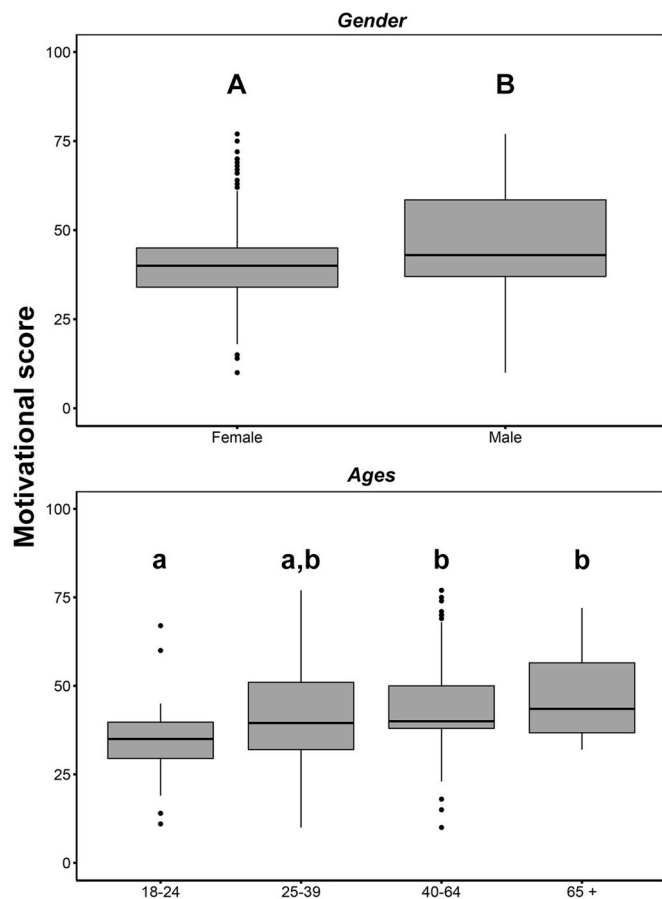


Fig. 4. Motivational scores and demographic differences of the public regarding lionfish impacts and support towards its research and management. Groups that do not share a letter were significantly different at $p < 0.05$.

Table 2

Experienced effects from the lionfish as reported by the stakeholders. N represents the number of the records for each effect.

Negative effect	N	Positive effect	N
Limits access to dive sites	6	Increase in diving tourism	5
Removes other fish	6	Food source	1
Environmental threat	2		
Health Hazard	1		
Destruction of equipment	1		

Table 3

Management measures suggested and number of times raised by the stakeholders.

Management measures	Number of records
Fishing	10
Coordinated removals	6
Market creation	6
Spearfishing with scuba	5
Other culling	5
Financial incentives	3
Management	3
Trapping	2
Research	2
Project impact monitoring	2
Education and awareness	2
Competition	1

stakeholders mostly agreed and the public disagreed with the statements (Pearson's chi-squared test, $\chi^2 = 113.4$, $df = 2$ and $\chi^2 = 72.6$, $df = 2$, respectively, $p < 0.001$) (Fig. 3).

3.4. Demographic differences in knowledge and perceptions about lionfish

The demographic parameter that played the most important role for the public regarding the knowledge about the lionfish was the gender. Specifically, men showed that were more probable to have heard and recognise the lionfish than women (Binomial GLM, $Z = -2.02$, $p < 0.05$). The motivational scores derived from the questions associated to the public perceptions of lionfish (i.e. impact of lionfish and support towards its managements and research; see questions 4 and 5 in Appendix) were shown to be influenced by the gender (Multiple linear regression, $df = 1$, $F = 10.17$, $p < 0.05$) and the age (Multiple linear regression, $df = 3$, $F = 6.71$, $p < 0.05$). Specifically, men showed higher motivational response scores (more positive) than women (Mann-Whitney, $W = 20144$, $p < 0.05$), and the youngest ages were less positive compared to older people (Kruskal-Wallis, $\chi^2 = 17.30$, $p < 0.05$) (Fig. 4). For stakeholders, none of the demographics showed to be responsible for their responses, neither on the knowledge nor the perceptions about the lionfish.

3.5. The abundance of lionfish

Stakeholders were asked if and when was the first time that they observed a lionfish in the waters of Cyprus. 81% ($n = 87$) answered that they had seen a lionfish in Cyprus marine environment, 16% ($n = 17$) answered that they had not seen; and 4% ($n = 4$) did not answer at all. According to the responses, most first sightings occurred

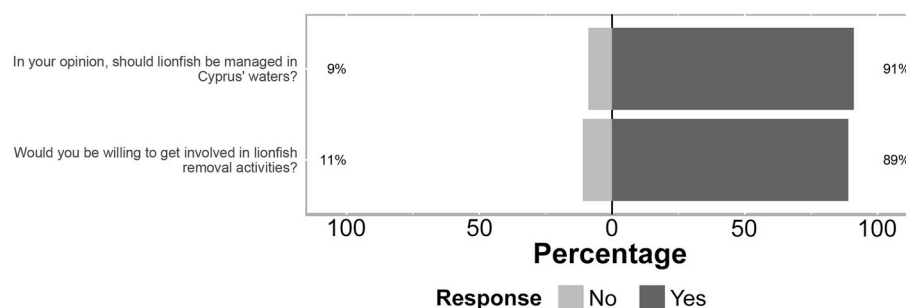


Fig. 5. Perceptions of stakeholders about lionfish management and their willingness to get involved in removal activities.

between 2014 and 2015 ($n = 41$) with some first sightings occurring in 2012 ($n = 6$).

In response to what is the maximum number of lionfish that they have seen in a group, stakeholders' answers varied (mean = 7, $\sigma = 8.60$); with the maximum recorded value of 60 lionfish individuals in one group. Most of the interviewees who observed grouped lionfish weren't able to describe the surrounding habitat where they found them (64%). From those who answered, rocky substrate was reported as the most preferred by lionfish (54%) followed by shipwrecks and artificial reefs (33%).

Stakeholders were asked if they believe that the lionfish population is increasing or decreasing. The vast majority of the respondents stated that the population has increased both since their first encounter with lionfish (89%, $n = 83$) and since the last year (92%, $n = 79$). A minority of stakeholders stated that they had observed constant levels of lionfish. No respondents stated that they had observed a decrease in the population on lionfish.

3.6. Effects from lionfish

Stakeholders were asked if they have experienced any effect due to the presence of lionfish (i.e. personal, economic or environmental). From those who responded ($n = 99$), 73% answered that they had experienced no effects while 27% had experienced some effects (positive or negative). According to the responses, during the last year, 23% of the stakeholders had experienced some effects from the lionfish.

The experienced negative or positive effects, as reported by the stakeholders, are presented in Table 2.

3.7. Opinions on the management of lionfish

Stakeholders were asked if they believe (or not) that the lionfish in Cyprus should be managed, if they are willing to contribute in management efforts, and which measures they consider as the most eligible for lionfish management. Most stakeholders reported that the lionfish should be managed in Cyprus' waters and also that they are willing to get involved in removal activities (Fig. 5). Several possible management measures were raised by the stakeholders such as the creation of a market (for lionfish products, fishing, trapping and general culling of the lionfish population (Table 3).

The stakeholders were provided with specific reasons that could incentivize them in getting involved with removal actions. Using a scale of 0–10 with 0 being not willing at all and 10 being very willing, they were asked to state whether they were willing or not willing with each reason. The values indicated a very slight disposition towards agreement (Fig. 6).

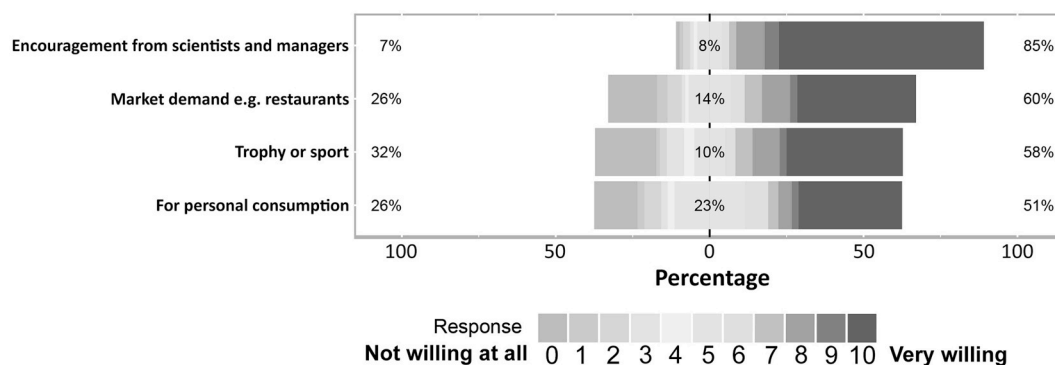


Fig. 6. Agreement of stakeholders for specific reasons to participate in removal lionfish efforts.

Table 4

Barriers and enablers that have been reported by the stakeholders to affect their involvement in removal action efforts.

Barriers	N	Enablers	N
No free time	10	Proper Management, training and support	13
Lack of knowledge/skill	6	Other	8
Health hazard	6	Financial support	7
During work hours	3	Equipment	5
Cost	2	Competition/Organised event	5
Improper management	2	Give licenses	3
Believe no action is needed	2	Weekend actions	2
License	1	Market creation	1

Further, the stakeholders were asked to state reasons that can act as barriers or enablers for them to be involved in removal action efforts. 30% of the respondents ($n = 32$) mentioned 'barrier' reasons while 41% ($n = 44$) mentioned 'enabler' reasons. The most commonly reported barrier was the lack of available time ($n = 10$) and the most commonly reported enabler was proper management, training and support ($n = 13$) (Table 4).

4. Discussion

4.1. Cyprus pioneer role in monitoring and understanding Mediterranean IAS

Cyprus represents the first hotspot of lionfish in the Mediterranean and the first EU country to be affected by Lessepsian immigrations. Thus, it has a pioneer role in understanding introduced species' dynamics, exchanging information, data and best practices including programmes related to public awareness or education. The latter is particularly important for the case of lionfish as the Atlantic experience has shown that its management requires sustained and long-term commitment from both the public and marine stakeholders [27–29].

4.2. Divergences in opinions, knowledge and attitudes

This study identified significant differences in the levels of awareness, recognition and knowledge about lionfish among members of the public compared with marine stakeholders. This dichotomy is to be expected since marine stakeholders in Cyprus are more likely to have encountered lionfish and be aware of potential impacts from their uncontrolled spread. In regards to perceptions, it is interesting to note that a change is already evolving, as a recent study has shown that of 415

stakeholders from Cyprus (mostly divers, fishermen, academics, managers) interviewed between 2012 and 2017, only 65% knew about lionfish and most were against culling [30]. In our survey, there was almost unanimous agreement from both the public and stakeholders that it is necessary to undertake research to understand the potential effects of lionfish, and that its numbers should be limited through management measures. Only five out of 108 indicated that the presence of lionfish may have positive effects on dive tourism.

A divergence in opinion regarding the consumption of lionfish and the purchase of products made from lionfish (e.g. jewellery) was observed. The public were more opposed to these statements rather than the stakeholders. Divergences between groups' opinions on management options was found in other studies [31–33]; attributed to diverse and often competing values and interests. Divergence can be also observed between individuals of the same group due to factors such as different attitudes, personalities and livelihoods [34]. In regards to fish consumption, several models have been proposed to explain consumer behaviour with often interrelated motivational factors taken into account including the availability of fish, meal preparation skills, perceived convenience, health involvement, negative feelings, attitude towards eating fish, social norms, moral obligations, confidence in evaluating the product, etc. [35].

It is natural that stakeholders with a strong affinity to the sea (e.g. fishers, divers) would be less opposed, more experienced and confident to trial the consumption of a new marine product. If lionfish are not part of the preferred diet (the public social norm) then consumption of the species would require some deliberation on behalf of the consumer. Taste, nutritional value and freshness (quality) of seafood are the overriding factors that influence seafood consumption and buying behaviour [36]. A recent study in the Mediterranean found that lionfish contains higher levels of protein and healthy fatty acids compared to native marine species [37], as it was previously demonstrated in the lionfish of the Atlantic [29]. The nutritional value of lionfish could be therefore promoted to influence the norms and attitudes of the public, and support its consumption in the Mediterranean.

Gender and age were found to significantly affect the opinions of the public regarding lionfish invasiveness and their support towards lionfish research and management. According to the responses, men were more likely to know of and be able to recognise a lionfish than women. In addition, men and older people were found to be more concerned about the potential impacts of lionfish and were more likely to support lionfish research and management; compared to women and younger people, respectively. Although women usually tend to report stronger environmental attitudes, concern and behaviours than men [38] and references therein), the differences found in this study can be attributed to the fact that less women are engaging in marine and (recreational) fishing activities in the region. Younger people were surprisingly less concerned about the problem; in contrast to numerous early studies which suggest that they should be more environmentally concerned (e.g. Refs. [39–41]). Our study agrees with recent studies, which indicate underlying changes in society and declining trends in youth's environmental attitudes and behaviours [42–44]. Different approaches should be applied to stimulate the interest on the lionfish and involvement of public based on their demographic differences (i.e. age and gender).

4.3. Lionfish management using a participative citizen approach

In terms of getting involved in lionfish management, most of the stakeholders (i.e. more than 90%) were willing to get involved. Stakeholders' top-suggested lionfish management measures were fishing, coordinated removals and market creation. However, less than 60% of the stakeholders considered market demand, trophy or sport, or personal consumption as good reasons to incentivize their participation in lionfish removals. On the other hand, encouragement from scientists and managers appears the most preferred incentive, reported by 85% of

the stakeholders. This is in line with the most commonly reported enabler (to future involvement) which was focussed on management, training and support; indicating that stakeholders need to be approached by the scientific community, educated, trained and encouraged, in order to participate in the management of invasive species such as lionfish.

The fact that lionfish encounters since 2012 remained vivid in the memory of stakeholders agrees with the results of a recent Lebanese stakeholder survey [45]; and reinforces the evidences that lionfish can be ideally used in a participative citizen approach to monitor and control its invasion [45]. In the Caribbean, surveillance systems driven by citizen scientists, and local removal efforts that make use of trained volunteers have been successful in reducing local densities and biomass of lionfish [46]. Coordinated approaches such as fishing derbies [23] can form part of a management strategy as well as bringing economic benefits to the hosting community [47]. The public (though not asked in this questionnaire) may also get involved. It is documented that successful conservation actions require integration of processes that can influence human behaviour [48]. Such processes include motivational messages that enable achievable, specific actions [48]. Motivation messages aimed at the public and stakeholders alike have been used in both the USA and the Caribbean to motivate the hunting and consumption of lionfish including campaigns entitled "Eat them to beat them" and "Do Your Civic Duty, Eat This Fish!" [49]. Whilst the success of such campaigns has not been evaluated, it may be considered that such an approach may improve the public engagement with lionfish removal efforts.

4.4. Application of a multidisciplinary evaluation framework

The integration of the ecological, social and economic sciences into a research evaluation plan can serve to connect the public with a natural environment that underpins aspects of human well-being. The application of an evaluation framework to assess impact (or performance of a management measure) of a project policy or programme can allow for statistical or observational analysis of 'change' that underlies interventions [50,51]. The aim of such approach would be to demonstrate how severe a lionfish invasion may be on the Cypriot (and wider regional) economy and how they pose a direct threat to human health. This interdisciplinary approach is an essential component of a future research plan to influence public knowledge and perceptions and to embed this in a long-term management strategy for lionfish.

5. Conclusion

Stakeholder responses corroborate evidence that lionfish are increasing in abundance around the island of Cyprus although most of the public are unaware of this. Stakeholders have concerns that there may be significant impacts on the biodiversity and ecological functions of the region that support human wellbeing (e.g. fisheries, recreation and tourism) if left unmanaged. Moving forward, it is imperative to improve the public's knowledge base on lionfish to influence local and regional political processes about lionfish control through management interventions. Interdisciplinary approaches that support economic and social research along with ecological studies can serve to reconnect the public with the natural environment.

The public were not strongly supportive of a new fishery for local lionfish consumption. A campaign that challenges motivational factors such as social norms, feelings, moral obligations, confidence, attitudes and preferences towards traditional seafood, along with targeted studies on the nutritional value of lionfish in comparison to the preferred seafood dietary choices may engender a shift in consumer choice and create a market for this commodity.

Both groups of respondents expressed strong support for research and management and the stakeholder group demonstrated that they will get involved in management activities. Persistent encouragement,

support and training by scientists are reported as essential motivational drivers towards their involvement. To maintain stakeholder engagement it is necessary to robustly evaluate management interventions on indicators linked to economy, ecology and society. Such knowledge can inform an efficient and adaptive management process that can be shared with wider regional partners in the Mediterranean basin.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.marpol.2019.02.052>.

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